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Preservation of borings: contrasting examples from the type Maastrichtian (Upper Cretaceous), southern Limburg, the Netherlands

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ABSTRACT

The taphonomy of trace fossils and their substrates remains an understudied facet of sedimentary geology. Contrary to common prejudice, trace fossils are not invariably preserved in situ, but may be exhumed and reworked following lithification. The trace fossils most commonly found ex situ are borings in mobile shelly substrates. Two notable, but contrasting, examples of post-mortem transport of borings are described from the Maastrichtian (Upper Cretaceous) of southern Limburg, the Netherlands. A long, unusually straight and complete calcareous tube assigned to *Teredolites longissimus* Kelly and Bromley is an organically secreted internal mould, produced by a teredinid or pholadid bivalve boring in wood and lining their tube. Strictly, this is part of the body fossil of the producing bivalve, but it is also an organically generated internal mould of the boring. A flint steinkern of a right valve of *Crassatella bosquetiana* d'Orbigny preserves a suite of silicified borings. *Caulostrepsis taeniola* Clarke is a U-shaped boring with a vane connecting the parallel limbs. *Talpina* isp. is a slender, simple, branched tunnel. Most unexpected, *Spirichnus spiralis* Fürsich et al. is a spiral 'worm' boring hitherto only known from the Upper Jurassic. This stratigraphic gap is likely an artefact; only mouldic preservation of the bored substrate would expose the distinctive *Spirichnus* boring. These ichnofossils are united in their occurrence in unusual preservational systems.

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1. Introduction

Trace fossils and taphonomy, including both biostratinomy and diagenesis, are aspects of sedimentary geology that are not commonly seen to mix. One of the essential pieces of intelligence taught to all of us as undergraduates is that trace fossils – mainly burrows and trackways – are almost inevitably preserved in situ (e.g., Clarkson, 1993, p. 21). Yet once lithified a trace can be reworked like any other clast. For example, it is not unusual for tetrapod tracks to be eroded out of cliffs in areas of active coastal erosion, such as the Lower Cretaceous of the Isle of Wight (e.g., Martill and Naish, 2001) and the Jurassic of the Yorkshire Coast (e.g., Whyte et al., 2006), both in the United Kingdom. Lithified invertebrate burrows can also be reworked, such as those from the Jurassic of the Boulonnais, northwest France (Ager and Wallace, 1970), and burrows preserved in flints from Upper Cretaceous chalks of northern Europe (Kennedy, 1970, pl. 3; Reich and Frenzel,

2002; Gravesen and Jakobsen, 2013) that may be collected from modern beaches.

The most likely trace fossils to appear as such remanié elements are borings in mobile clasts such as shells and cobbles. One instructive example amongst many is a Late Cretaceous belemnite collected from the beach in north Norfolk (United Kingdom) that had been bored by sponges (*Entobia* isp.) in both the Cretaceous and Holocene (Donovan and Lewis, 2010). There is also abundant evidence of reworking of borings in the geological past, such as in the Middle Miocene Grand Bay Formation, well exposed on the east coast of Carriacou, the Grenadines (Lesser Antilles). This preserves diverse sedimentological, palaeontological and ichnological evidence that shows incontrovertibly that its origin was in a deep-water turbidite basin (Donovan and Harper, 1999; Donovan et al., 2003). Borings are rare, but invariably occur in bioclasts derived from shallow-water settings (Pickerill et al., 2002a,b, 2003).

Thus, the reworking of borings is well established and their taphonomy a distinct aspect of many sedimentary systems. Herein, we describe a pair of dissimilar specimens collected from the type area of the Maastrichtian Stage (Upper Cretaceous) in southern Limburg, the Netherlands. These specimens are highly contrasting,

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yet instructive. They almost certainly came from the same formation, albeit different members and lithofacies. Their preservational dissimilarities are considered enlightening, providing information on the style and preservation of borings in the type Maastrichtian.

2. Localities

Both of the specimens considered below were donated to Naturalis Biodiversity Center by the Museum Mijnbouwkunde Nederland as part of a transfer of collections from the Museum of Mineralogy and Geology at Delft. The main palaeontological collections were transferred from Delft to Naturalis in the 1980s. The mineralogical collections followed in 2013 and 2014, inclusive of the final residue of the palaeontological material. It was this latter transfer that yielded the specimens described below.

Labels contain identical, but minimal, data regarding locality and horizon, stating merely: 'Krijt, Maastrichtien Zuidlimburg'. This is easily translated as 'Chalk, Maastrichtian southern Limburg'.

Although lithologically contrasting, it is almost certain that these specimens came from the same locality, most likely the ENCI-HeidelbergCement Group quarry at the Sint-Pietersberg, south of Maastricht.

RGM 792 278 is identified as *Crassatella bosquetiana* d'Orbigny on the label. In general, crassatellid bivalves are common only at two widely disjunct intervals within the Upper Cretaceous (Campanian–Maastrichtian) succession of the study area (Bosquet, 1860, 1868; J.W.M. Jagt, pers. obs.). Van der Weijden (1943) recorded three species from lower Campanian, sandy glauconitic strata of the Vaals Formation, namely *Crassatella aequalis* Holzapfel, 1889, *C. arcacea* Roemer, 1841 (including var. *subarcacea* Böhm, 1885, which may also be a distinct species) and *C. symmetrica* van der Weijden, 1943, that are mostly preserved as internal and external moulds, and more rarely as (articulated) silicified shells. Within the Maastricht Formation, of late Maastrichtian age, crassatellids appear to be restricted to the Nekum Member, although a single internal mould is on record from the upper Meerssen Member (J.W.M. Jagt, pers. obs.). The lower

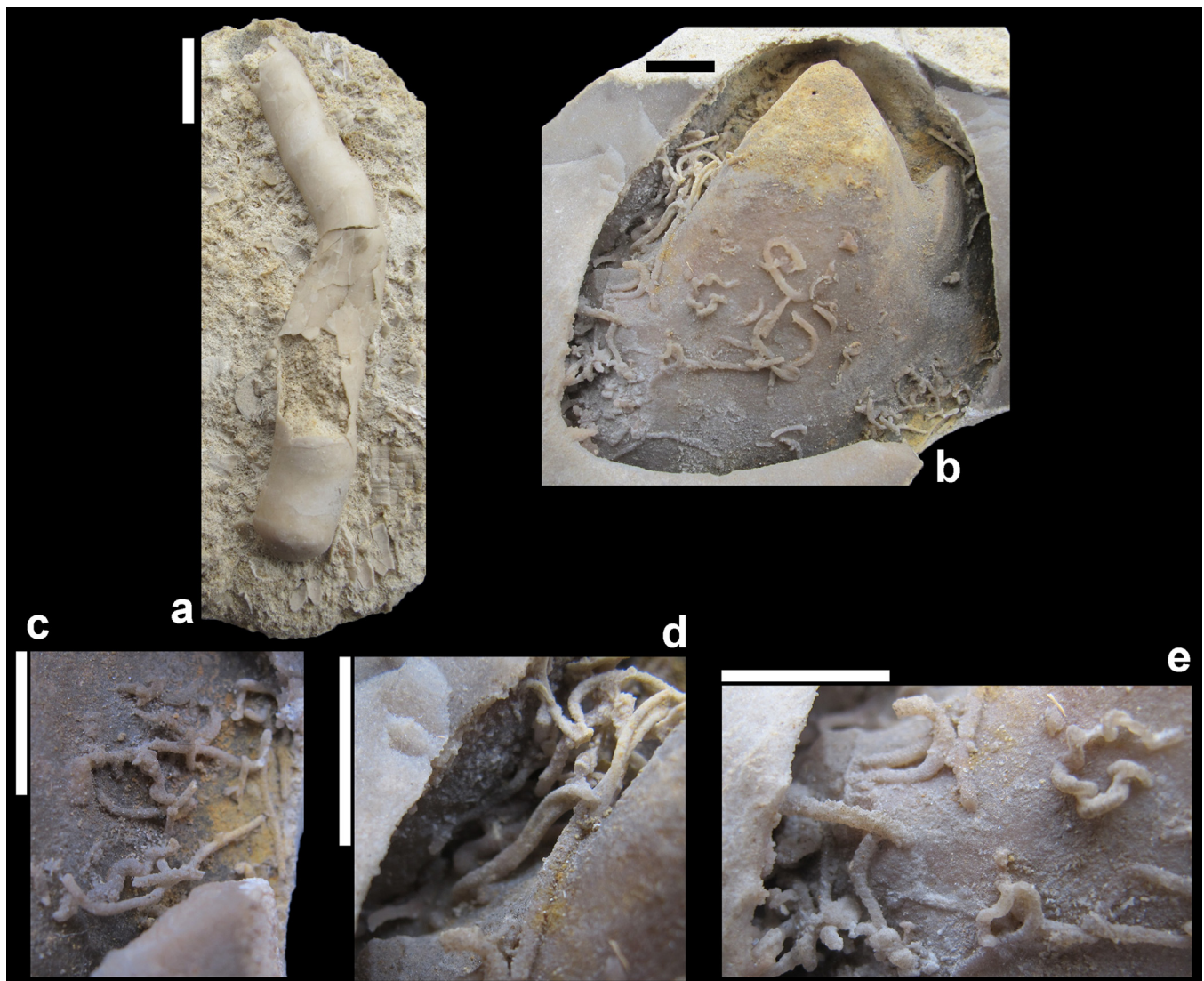


Fig. 1. Borings from the type Maastrichtian (upper Maastricht Formation, Nekum and possibly basal Meerssen members; upper Maastrichtian, Upper Cretaceous), Maastricht area, southeastern Netherlands. (a) RGM 791 279, *Teredolites longissimus* Kelly and Bromley preserved as a calcareous tube secreted by the producing bivalve. (b–e) RGM 792 278, *Crassatella bosquetiana* d'Orbigny, internal mould of a right valve preserved in flint and retaining fills of borings. (b) Whole mould of valve showing distribution of numerous small borings. (c) *Talpina* isp. (d) *Caulostrepsis taeniola* Clarke. (e) *Talpina* isp. and *Spirichnus spiralis* Fürsich, Palmer and Goodyear. Specimens uncoated. All scale bars represent 10 mm.

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